

Aqueous Cleaning Design Presentation

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INTRODUCTION

The phase-out of CFCs and other ozone depleting chemicals has prompted industries to re-evaluate their present methods of cleaning. It has become necessary to find effective substitutes for their processes as well as to meet the new cleaning challenges of improved levels of cleanliness and to satisfy concerns about environmental impact of any alternative selected.

One of the most popular alternatives being selected is aqueous cleaning. This method offers an alternative for removal of flux, grease/oil, buffing compound, particulates and other soils while minimizing environmental impact.

What I will show are methods that can be employed in an aqueous cleaning system that will make it environmentally friendly, relatively simple to maintain and capable of yielding an even higher quality of cleanliness than previously obtained. I will also explore several drying techniques available for these systems and other alternatives along with recent improvements made in this technology.

OVERALL SYSTEM CONSIDERATION

When considering any type of cleaning system, a number of variables should be determined before selecting the basic configuration. Some of these variables are:

- Soil or contaminants being removed from your parts.
- The level of cleanliness required.
- The environmental considerations of your area.
- Maintenance requirements.
- Operating costs.

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- Throughput requirements.
- Dryness requirements.
- Space and cost constraints.

SOIL, CONTAMINANTS, AND CLEANLINESS

When considering the basic configuration, the type of soils /contaminants and the level of removal must be factored into the equipment's basic design. Some of the key factors are:

The types of surfactants used are determined by the types of soils, the amount of contaminant, material of the parts and the cleanliness requirement.

- The types of soils help determine the amount of and type of filtration required. For example, if oils are the major contaminants, some type of oil removal system should be considered in the wash station. The amount of oil and parts cleanliness requirements will help determine the type of oil removal system. A simple decanter separator will remove large amounts of oil, but the level of removal is less than a more expensive membrane system. However, if the cleanliness requirements are very high, a membrane system may be the most effective approach. Of course, there are other degrees of oil removal, such as coalescing filter systems. Coalescing filters will meet requirements in the middle of the decanter and membrane systems.

If, however, the contaminants are mainly particles, only a simple recirculating filter system would be required. The type of filter best suited for the application will again be determined by the amount of contaminant and the cleanliness requirements.

- The amount of contamination and the cleanliness requirements will also help determine the number of wash and rinse stations needed as well as water level requirements. Generally, the larger the amount of soil that must be removed and the higher the level of cleanliness required, the more wash and rinse stations that are needed. Also, as the cleaning requirements increase, so must the quality of the water being used.
- Over-specifying any of these levels only increases the amount of equipment and cost unnecessarily.

ENVIRONMENTAL CONCERNS

When considering the environmental impact of cleaning systems, one should look at the process in terms of its ozone depletion potential (ODP), global warming effect, energy usage, use of consumable resources, toxicity and safety. All of these factors should be carefully evaluated when selecting a cleaning process. An aqueous cleaning system has no ozone depletion potential, minimal global warming effect, low toxicity, and it is safe. It can be designed for reasonable energy usage while minimizing the amount of considerable resources (water) that are used.

The system designed to conserve energy should have as many of the following features as possible:

- Recirculated hot air drying, which can reduce energy usage as much as 75 percent over a nonrecirculating system.
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- Minimize compressed air for blow-off and/or drying.
- Improved surfactants that allow easier rinsing in cooler water.
- Rinse agents that can speed up drying times.
- Improved rinsing by using ultrasonics and filtration, thereby reducing overall water flow.
- On many metal parts, the use of rust inhibitor minimizes the usage of energy and water.
- Filtration and oil removal to extend wash tank life.
- Multiple wash tanks to reduce soils loading on the rinse tanks.
- A heat recovery system on overflow of any water to drain.

It is important not to over specify requirements and, therefore, create additional and unnecessary energy and water usage. Consideration should be given to water reduction techniques such as:

- A gross tank to reduce detergent carry-over.
- Ultrasonic agitation to reduce overall process time and rinse water flow rate.
- Closed-loop process that allows overflow water to be reused.
- Improved fixturing to reduce water drag-out, to improve rinsing and to speed drying.

EASE OF MAINTENANCE AND OPERATION

Another important area is ease of maintenance and operation. Issues to be considered should include:

- Convenient access to routine maintenance items such as filters.
- How are detergents dispensed to the system? Should detergent injectors or a metering pump system be added for automated dispensing of detergents?
- Should an automated handling system be used to process parts?
- Does the system use auto drains and fills versus manual valves?
- Is the de-ionized (DI) rinse water continuously monitored and is auto makeup available?
- What type of plumbing is used (compression fitting versus NPT pipe)?
- Is high flow filtration continuously used?
- Have the cleanliness level and the amount of soil to be removed been considered when selecting the filter?
- What other instruments should be considered? Options include pressure gauges, temperature controllers, pH monitors, resistivity monitors and turbidity monitors.

THROUGHPUT AND DRYNESS REQUIREMENTS

When selecting a basic design, a major consideration should be the amount of parts that are to be processed through the system in a given period of time. This will affect:

- The size and configuration of the system.
- Overall equipment and operating costs.
- Type of automation, if required.

Since drying comprises a significant portion of time in any process, specifying only the level required is fairly important. In some cases, you may not require drying even though it may have been done in the past. If drying is essential, specifying it correctly impacts the type of equipment used and the amount of time required.

SPACE AND COST CONSTRAINTS

Available space and overall cost will impact the type and design of the equipment. However, in both cases, using artificially low values may cause the equipment design to be negatively impacted to a point that prevents you from meeting many of your other objectives in a prudent manner.

However, if all the previously mentioned factors are carefully balanced against your ultimate goal, an aqueous system can be configured to meet your needs.

BASIC ULTRASONIC AQUEOUS CLEANING SYSTEM

Now that many of the basic variables have been considered, let's build an ultrasonic aqueous cleaning system that would meet many of the fundamental needs. First we must look at three basic building blocks of the system: WASH, RINSE and DRY.

As we discuss these system components, remember that the system being described will actually yield parts that have a higher level of cleanliness than that of a roughly comparable solvent cleaner. Our theoretical system will also incorporate many of the features discussed earlier.

WASH

The wash station is designed to remove complex soils and particulates completely from a wide variety of parts utilizing biodegradable detergents. The major features of this station are: ease of use, prolonged bath life, minimal drag-out, effective removal of all soils and minimal waste. A typical two-tank configuration is shown in Figure 1.

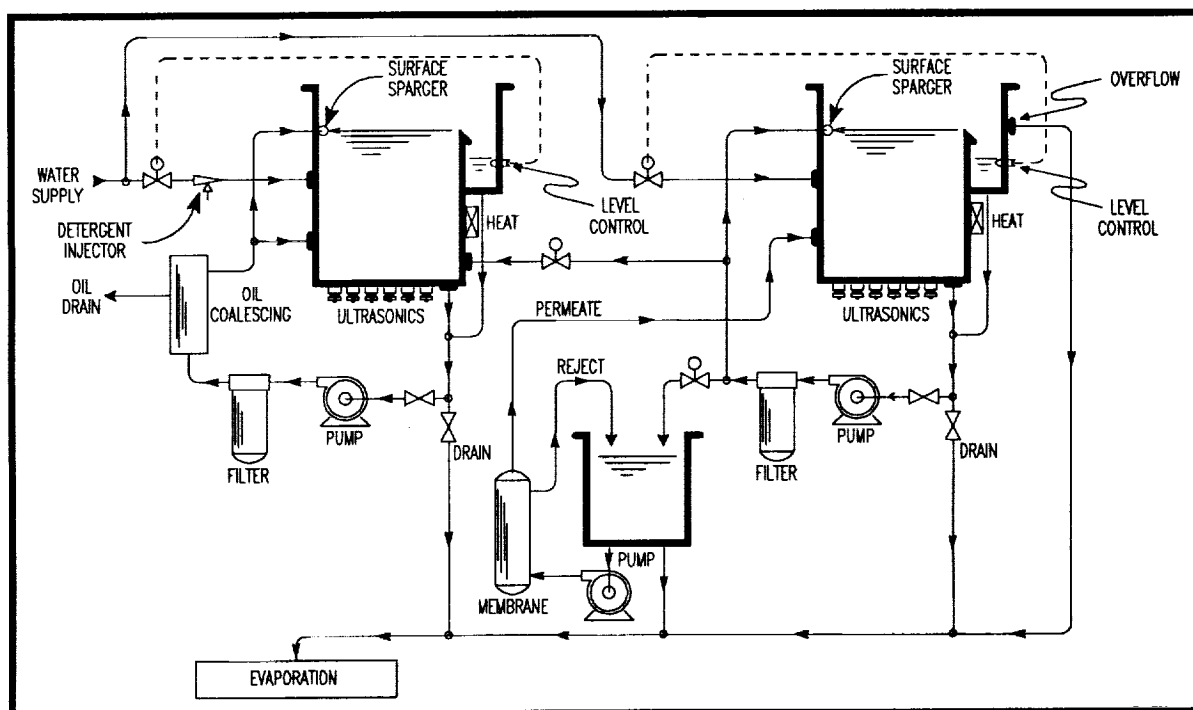


Figure 1: Cleaning Tanks.

Both tanks utilize bottom-mounted ultrasonics to assist in the thorough removal of all soils. Tests have shown that with proper power controls most parts can be effectively cleaned utilizing ultrasonics.

The tanks illustrated above also incorporate a high flow recirculation filtration system with multiple return ports. Recirculation filtration is important to minimize the redepositing of particulate on components and to extend the bath life. With proper control of the flow return to minimize turbulence and provide a proper

sweeping action, flow rates covering 50 percent of the tank volume per minute can be utilized with no impact on the ultrasonic activity.

The first tank of the wash section will frequently have a detergent injection and automatic water makeup system to maintain a constant level of water and detergent in the bath. The detergent level in the second tank is allowed to fluctuate as the detergent is dragged in the first tank.

Through the use of an oil coalescing system and a surface skimmer, oils can be removed easily from the wash tank if an appropriate non-emulsifying detergent is used. To prolong the life of the second wash and to provide a higher level of cleanliness, a membrane system may also be incorporated. The savings realized are a function of water usage plus disposal cost and can range from \$10,000 to \$100,000 per year.

The two cleaning tanks must be dumped when either the effectiveness of cleaning has dropped below acceptable levels or the concentration of detergent in the second tank is too high. This is accomplished by first dumping Tank 1 into an evaporator holding tank. The evaporator flashes off the water, leaving a small volume of solid waste that must be disposed of. It should be noted that the average operating cost of an evaporator is 6 cents to 10 cents per gallon evaporated. These figures can be used to determine if such a system is an effective method of minimizing your disposal cost per year or if some other method should be considered.

Tank 1 is refilled by dumping Tank 2 into Tank 1. Tank 2 is then refilled with clean water or with water from the first rinse station. The use of a two-wash tank configuration reduces the frequency of tank solution changes, minimizes the detergent carried over into the rinse tank and increases the consistency of cleaning achieved with the system.

RINSE

The rinse station is designed to thoroughly rinse the detergent and remaining particulates from the components utilizing the minimum volume of water possible.

The rinse station has been divided into two parts: Gross detergent removal and final rinse. The gross detergent removal tank is designed to remove the majority of the detergent utilizing a combination of spray and immersion with a closed-loop water supply. The tank consists of a one-sided ultrasonic overflow tank with

a two-sided spray system above it and a high-flow recirculation pump and filter system (Refer to Figure 2).

The oversized overflow trough is utilized as a reservoir for the pump and filter system. The filtered water is returned either to the bottom of the rinse tank or to the sprays. The system operates as a closed-loop until the maximum conductivity limit is reached. The water from the final rinse stage is then fed into the tank that overflows into the second wash tank. The entire tank is dumped into the second wash tank where the wash tank solutions are changed. The tank design allows the majority of the detergent to be removed with minimal fresh water input (Refer to Figure 2).

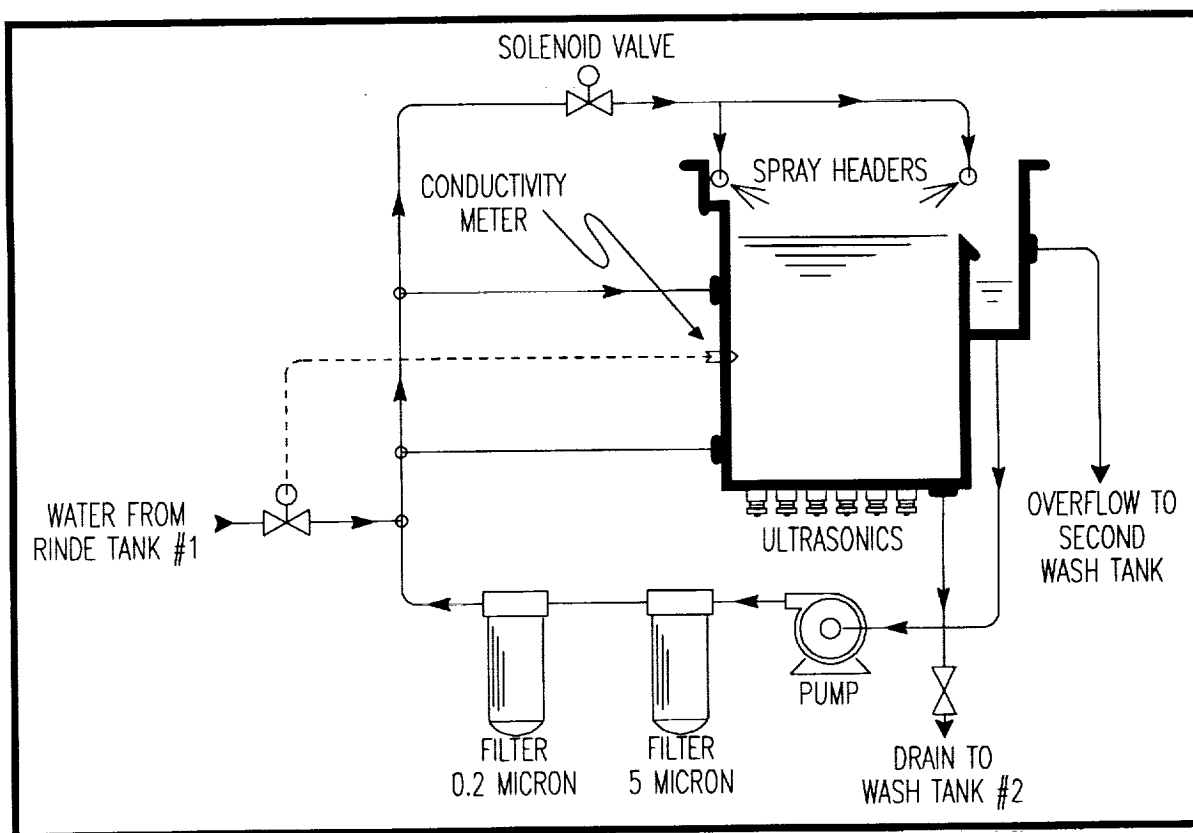


Figure 2: Gross Rinse Tank.

The final rinse stage consists of two cascading overflow rinse tanks with ultrasonics in both. The rinse tanks have spray rinses above them for final

rinsing. The first rinse tank is fed from the overflow of the second rinse tank. The first tank overflows into a holding reservoir that feeds a pump that pumps the water to a surfactant-stripping and water-polishing system for recycling. The return from this recycling system feeds the second rinse tank (Refer to [Figure 3](#)). Fresh water is fed into the reservoir tank. The last rinse should be hot to expedite drying.

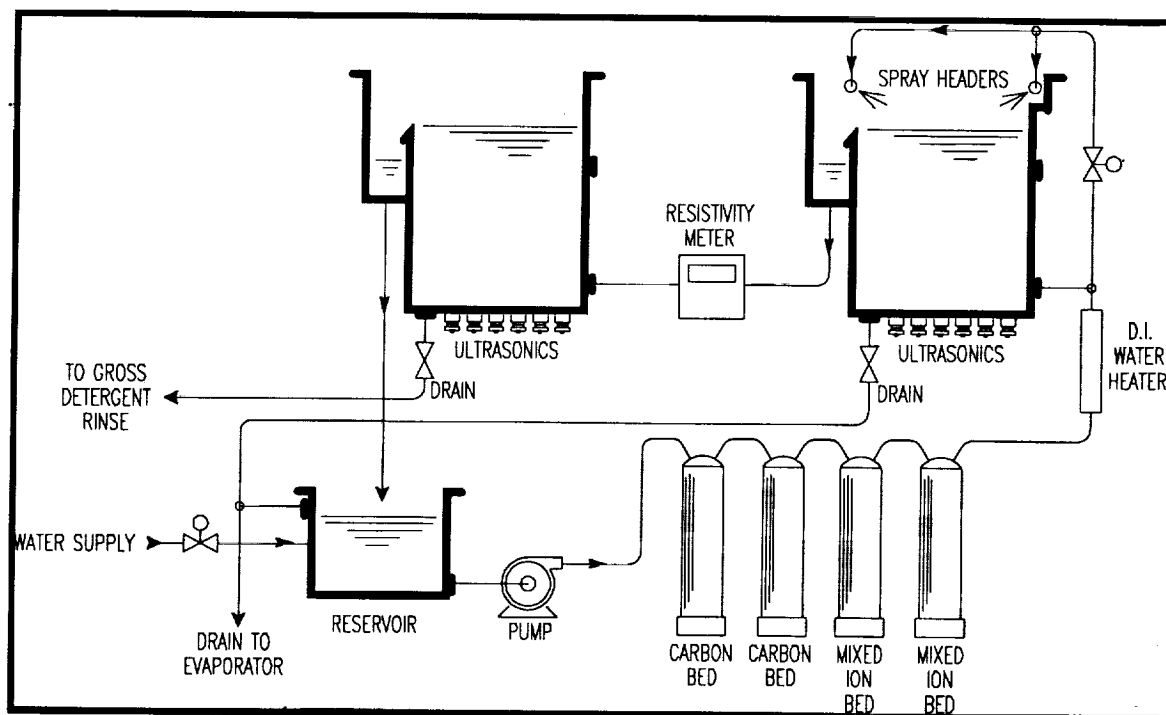


Figure 3: Final Rinse.

The closed-loop design allows the system to operate with very low water requirements while providing thorough rinsing before the drying stage. No detergent residues can be present if spot-free drying is to be achieved.

A closed-loop water system used in this manner with a 2 gal/min flow rate and a drag-over of approximately 1000 grams of a pH neutral surfactant per day would have an approximate operating cost of \$ 4,600 to \$6,300 per year. Most systems are being designed so that closed-loop rinse water recycling can be added at a later date.

DRYING

There are many new non-CFC drying techniques available, but the most widely used is high efficiency recirculating hot air. The high efficiency design utilizes large volumes of moderate temperature recirculating air to remove water from a wide variety of components. The air distribution plenums are usually located on opposed sides with a bottom return for even air flow. The air recirculating system includes HEPA filters, inline air heaters and adjustable air discharge and makeup ports to control the humidity in the recirculating air. The recirculating hot air design is much more energy efficient than conventional blow-off designs and more versatile in the variety of components that can be used.

The limitation of hot air is that it cannot remove water from deep blind holes, cupped pans or surface adsorbed water. If components with these characteristics are to be dried, a secondary drying process is often required with the most widely used process being vacuum drying. In this process, a warm, partially dried component is placed in a heated vacuum chamber which is pumped down to 4 to 10 torr to flash off the residual water. This process is very efficient in the removal of small films of water, but it will not successfully remove large volumes or puddles of water. With hot air followed by vacuum drying, most components can be completely dried spot-free.

Several other new non-CFC drying techniques are available for use in precision cleaning. If components with large flat surfaces such as glass plates are to be dried, capillary drying should be used. Capillary drying involves the slow removal of components from hot DI water. The surface tension of the water causes water to be pulled off the surface and the component left dry. If large volumes of parts are to be dried utilizing hot air, a tunnel dryer may be applicable. A tunnel dryer is a large recirculating hot air dryer that racks on a conveyor.

IPA DRYER

Alcohol can be used effectively as a drying agent by immersing parts into an alcohol bath. The alcohol bath essentially captures residual water. This water-capturing process is accomplished by the cracks and crevices inherent in the alcohol's molecular structure that function as absorbents.

The drying techniques described are just some of the new non-CFC precision drying techniques available. With correct implementation, any components can be dried with a non-CFC drying technique.

TYPICAL SYSTEM

The configuration of an aqueous cleaner can vary widely depending upon the wide variety of parts to be cleaned, the level of cleanliness required and the throughput requirements. In its simplest form, the system can be a single wash, rinse and dry tank in a small console. For more complete cleaning it may take multi-stages of each technique as I have described here. One such system that has been used extensively by the disk drive industry is shown in Figure 4.

This design reduces the system footprint by 25 percent without sacrificing the effectiveness of the cleaning. The trade-off is that the reduced system will require more careful maintenance of the cleaning solution and will increase the use of rinse water.

The other area where compromises in design are often required is in rinse water recycling. The operating costs of present systems are sometimes difficult to determine. However, a closed-loop system can be a cost-effective alternative. Considerable research is being performed in this area to identify cost-effective recycling systems as well as cleaning agents that are easier to recycle.

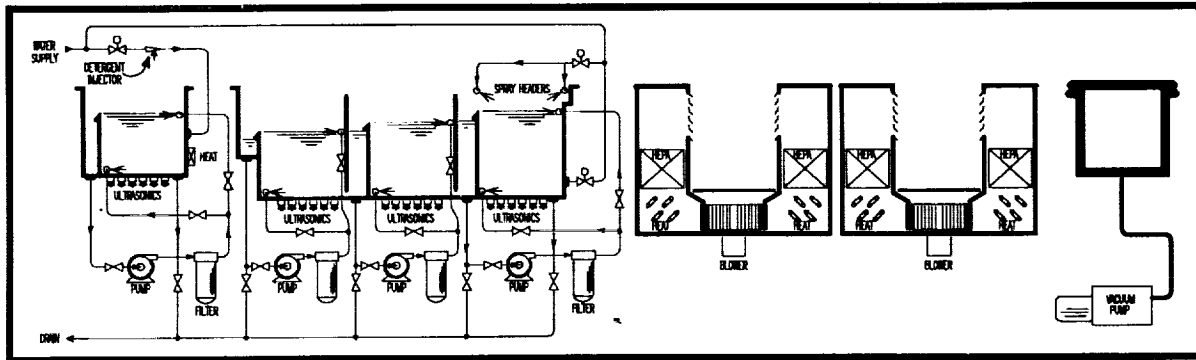


Figure 4: Typical System.

This system uses one wash, three rinses and two recirculating hot air dryers followed by a vacuum dryer. When automated, this system can deliver a basket of parts every 6 minutes to 7 minutes with a single-headed transport system. If an additional head is added, the throughput goes to 3.5 minutes to 4.5 minutes. The following chart shows typical cleaning results obtained with a similar system and compares them to parts cleaned in an ultrasonic CFC degreasing system.

REFERENCE 1

Comparison of Cleaning Data CFC Versus Aqueous Cleaning System

<u>Test</u>	<u>Units</u>	<u>Before Cleaned</u>	<u>CFC Cleaned</u>	<u>Aqueous Cleaned</u>
Ion Chromatography Sulfate	UG/IN ²	0.50	0.400	0.300
Ion Chromatography Nitrate	UG/IN ²	0.20	0.150	0.100
Ion Chromatography Chloride	UG/IN ²	0.80	0.750	0.500
Ion Chromatography Fluoride	UG/IN ²	0.60	0.200	0.030
Non-Volatile Residue (NVR)	UG/IN ²	0.05	0.040	0.020
Densitometer (Particulate)	-----	0.03	0.010	0.005
Dryness Test (Moisture)	UG/IN ²	-----	0.030	0.030
Haze Test (Corrosion)	-----	-----	-----	Better

CONCLUSION

There are a number of features that must be considered when evaluating a precision cleaning system, all of which will affect the system's environmental impact, ease of operation and degree of cleanliness. But I believe that I have shown that there is an environmentally sound and user friendly precision aqueous cleaning technology available that will produce parts with a higher level of cleanliness than those achieved in a CFC cleaning system.

